Team C: Column Robotics

Job Bedford, Cole Gulino, Erik Sjoberg, Rohan Thakker

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Autonomous Searching and Docking

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I. Introduction

This document will showcase the test plans for Team C for MRSD Project II. The major tests outlined in this document cover three main functional areas: "Search for and Approach Wellhead", "Align Self with Wellhead", and "Align and Dock with Wellhead Dock Feature". The tests outlined in the document are designed to test the effectiveness of each of these functional areas throughout the semester. Tests showcased before the SVE are designed to showcase the progression of the project throughout the semester in each of the three functional areas.

In order to test these three functional areas, we will need to showcase subsystems in: computer vision and object/tag recognition, localization, autonomous hovering, autonomous docking, position control, etc. Some of the tests are designed to test one or more of these subsystems. Other tests are designed to test the effectiveness of the integrated system on a larger functional area.

This document will begin by explaining some of the logistics of the project and then move into the schedule of the tests for the project review and the Spring Validation Experiment (SVE). Finally, this test plan will show a one-page outline of each of the major tests throughout the semester.

II. Logistics

There are some major logistical considerations that must be taken into account by Team C during the testing phases this semester including location, equipment, and test platform.

The tests will all be carried out in the B-Level basement at Newell-Simon Hall (NSH). The area used for the Fall Validation experiment will be the area where most of the tests will be carried out. Some tests, including hover tests, where very little motion in the X-Y plane is expected will be carried out within the net in the lab.

There is not much testing equipment that we will need. Most of the equipment will be build to model some of the infrastructure for the problem. We will need to build a wellhead to go along with the dock that was constructed during the Fall. We will also need to make use of tags for recognition and position control around the dock and the wellhead.

The final logistic matter concerns the test platforms. We will be running tests on both the AR.Drone and the Iris+ throughout the semester. Some tests will be performed on the AR.Drone while others will be performed on the Iris+. The tests performed on the AR.Drone are designed to showcase capabilities that we believe are extensible to the Iris+ platform. During the middle of March, we will be making our decision on which platform to chose. Once we have chosen a platform, we will be continuing the tests on only one platform.

III.   Schedule

Identifier	Capability Milestone	Associated Test	Requirements
Late January Progress Review 7	Iris+ hardware #2 AR.Drone base functionality	1. Backup Iris+ hardware completed 2. AR.Drone functionality complete	High speed state estimation during teleoperated control of iris+ via RC control (stretch: via ROS). Demonstrate in net.
Mid-February Progress review 8	Autonomous hovering	3. Autonomous hovering of Iris+ 4. AR.Drone Autonomous Docking	Test ability of drone to hover in place (within 1 meter) autonomously for > 60 seconds.
Late February Progress Review 9	Autonomous docking Integrated AR.Drone	5. Autonomous docking of Iris+ 6. Integrated AR.Drone demo	Autonomously recognize dock from above, approach and land on dock, confirm rigidity in 5 DOF
Mid-March Progress Review 10	Iris+ cone search	7. Cone search with Iris+	Iris+ searches for wellhead and locks on dock position. (stretch: Avoid walls)
Early April Progress Review 11	Iris+ integrated search and dock	8. Integrated Search and Dock	Iris+ searches for wellhead, locks on dock position, and autonomously docks.
Mid April Progress Review 12	Preliminary integration	9. Preliminary full system integration	Full demo: Take off, Search for wellhead, Orient to dock, land on dock, send signal.
April 22 and April 29 Spring Validation Experiment	SVE preview demonstration	10 SVE Preview: Demonstration of integrated system (Erik +	Full demo: Take off, Search for wellhead, Orient to dock, land on dock, send signal.

IV.   Tests

1. Backup Iris+ Drone Hardware
    a. Objective: The purpose of this test is to demonstrate a second complete, working Iris+ drone with all sensors and hardware integrated.
    b. Elements: This test will feature the following elements:
        i.   Hardware Subsystem - The complete and working hardware of the Iris+ drone
        ii. ROS Framework - The high-speed integration of our Linux SBC (ROS) and the flight-control firmware running on the Pixhawk microcontroller
    c. Location: MRSD Lab
    d. Equipment:
        i.   Iris+ Drone
        ii. Laptop PC
    e. Personnel:
        i.   Erik Sjoberg - Erik will demonstrate the functioning powered-up hardware
    f. Procedure:
        i.   Power up drone from battery and demonstrate blinking lights on SBC and PX4 Flow camera
        ii. Connect to drone from PC via Wifi network
        iii. Connect to ROS master running on Iris+ SBC
        iv. Display high-rate IMU and height sensor readings from Iris+ on PC
    g. Verification Criteria:
        i.   Iris+ SBC and PX4Flow sensor power up successfully
        ii. Able to connect to Iris+ SBC over wireless from PC
        iii. Able to see IMU data at over 150hz via rostopic hz
        iv. Able to see appropriate depth readings from sonar sensor via rostopic echo

2. AR.Drone functionality Complete
   a. Objective: Showcase ability to command drone and detect April Tag
   b. Elements: This test will feature the following elements:
      i. Hardware Subsystem - AR.Drone
      ii. ROS Framework - The high-speed integration of our Linux SBC (ROS) and the flight-control firmware running on the Pixhawk microcontroller
   c. Location: NSH B-level
   d. Equipment:
      i. AR.Drone
      ii. Laptop PC
      iii. April Tag
   e. Personnel:
      i. Job Bedford - Job will demonstrate the AR.Drone functionality
   f. Procedure:
      i. Initiate drone setup packages drivers communication and physical placement
      ii. Take off with drone, via mover node
      iii. Showcase planar movement with commands to drone.
      iv. Showcase April Tag detection pose and orientation estimates
   g. Verification Criteria:
      i. Drone should take off with mover noe command
      ii. Drone should obey all flight commands
      iii. rosnode should grant accurate estimate of tag locations within a 1m error margin.

3. Autonomous hovering with Iris+
   a. Objective: The purpose of this test is to demonstrate the ability to autonomously hover with the IRIS+. This will help us in implementing the cone search and docking states.
   b. Elements: This test will feature the following elements:
      i. Local Planning subsystem - to test the implementation of the "Hover In Plane" unit of the subsystem
      ii. World Modelling subsystem - to test the implementation of the "Pose Estimation" unit of the subsystem
   c. Location: NSH B-Level Basement
   d. Equipment:
      i. Iris+ Drone
      ii. Laptop
      iii. RC remote of IRIS+ Drone
   e. Personnel:
      i. Rohan Thakker - Rohan will be the operator who is required to run the commands for the drone.
      ii. Erik Sjoberg- Manually control the drone using the RC remote
   f. Procedure:
      i. Cordone off the area in the B-Level basement for safety.
      ii. Under manual control, take off with the drone and move into desired initial position and orientation.
      iii. Shift to autonomous control and run the command move the IRIS+ drone along a square trajectory.
      iv. Observe as the Iris+ autonomously navigates along the predefined trajectory.
      v. Shift to manual control and land the robot
   g. Verification Criteria:
      i. Iris+ was able to autonomously navigate the reference trajectory with less that +-2m of tracking error.

4. AR.Drone Autonomous Docking
   a. Objective: Showcase AR.Drone ability to land and dock with april tag detection.
   b. Elements: This test will feature the following elements:
      i. Hardware Subsystem - AR.Drone
      ii. April tags
   c. Location: NSH B-level
   d. Equipment:
      i. AR.Drone
      ii. Laptop PC
      iii. April Tag
   e. Personnel:
      i. Job Bedford - Job will demo the AR.Drone autonomous docking
   f. Procedure:
      i. Initiate drone setup packages drivers communication and physical placement
      ii. Job will command drone to take off and position it above the april tags with offset
      iii. Job will initiate the sequence
      iv. Drone will track and position itself above tag.
      v. Drone will descend and land within designated marker
   g. Verification Criteria:
      i. Drone should track and position itself above tag
      ii. Drone should descend and land in area of April Tag, with landing gear in markers
      iii. Marker will denote the level of accuracy in in docking.

5. Autonomous docking with Iris+
    a. Objective: The purpose of this test is to demonstrate the ability to autonomously docking with the IRIS+.
    b. Elements: This test will feature the following elements:
        i. Local Planning subsystem - to test the implementation of the "Land" unit of the subsystem
        ii. World Modelling subsystem - to test the implementation of the "Pose Estimation" unit of the subsystem using the APRIL Tag
        iii. Tactical Planning - to test the implementation of "Attempt Docking" unit of the subsystem.
    c. Location: NSH B-Level Basement
    d. Equipment:
        i. Iris+ Drone
        ii. Docking station with APRIL Tag
        iii. Laptop
        iv. RC remote of IRIS+ Drone
    e. Personnel:
        i. Rohan Thakker - Rohan will be the operator who is required to run the commands for the drone.
        ii. Erik Sjoberg - Manually control the drone using the RC remote
    f. Procedure:
        i. Cordone off the area in the B-Level basement for safety.
        ii. Place the docking station in the center of the area
        iii. Under manual control, take off with the drone and move to a position above the docking station such that the APRIL Tag is in the field of view of the downward facing camera
        iv. Shift to autonomous control and run the command to dock the drone
        v. Observe the IRIS+ attempt landing
        vi. Repeat from step (iii.), there more times
    g. Verification Criteria:
        i. IRIS+ was successfully able to land in the center of the funnels located on the docking station >1 out of four times

6. Integrated AR.Drone Demo
   a. Objective: Demo AR.Drone ability to complete SVE tasks. Merge task into continuous demo of take off, Tornado Search, Wellhead Alignment, Dock Alignment and Docking. This will complete our risk mitigation for the drone back up plan.
   b. Elements: This test will feature the following elements:
      i. Hardware Subsystem - AR.Drone
      ii. April tags
   c. Location: NSH B-level
   d. Equipment:
      i. AR.Drone
      ii. Laptop PC
      iii. April Tag
      iv. Wellhead mock up
      v. Dock marker
   e. Personnel:
      i. Job Bedford - Job will demo the AR.Drone integrated demo
   f. Procedure:
      i. Initiate drone setup packages drivers communication and physical placement.
      ii. Job will command drone to take off and position it in initial starting area.
      iii. Job will initiate the sequence.
      iv. Drone will proceed to tornado search staying within 7 meter demo area, until it detects wellhead marker.
      v. Drone will identify wellhead and align itself 1 meter in front of wellhead.
      vi. Drone will then identify and align with dock.
      vii. Drone will then descend and dock on dock.
   g. Verification Criteria:
      i. Drone perform tornado search within 7 meter square area.
      ii. Drone identifies and aligns itself 1 meter in front of wellhead.
      iii. Drone descends and docks on dock.
      iv. Drone landing gear will be within circular markers.

7. Cone Search with Iris+
    a. Objective: The purpose of this test is to showcase the system integration for two of the major functional elements of the project: "Search for and Approach Wellhead" and "Align Self with Wellhead". The integration of these two functional areas is highly critical for the success of the project. By showcasing the integration of the subsystems involved with these two functional elements, we will showcase that two-thirds of the major system functionality has been fully implemented and integrated.
    b. Elements: This test will feature the following elements:
        i. Vision subsystem - In order to recognize and lock on dock position, we must showcase that the vision system is able to recognize tages and get position estimates from them.
        ii. Control subsystem - In order to send waypoint information for the predefined cone-search path, we must have accurate position control in order to have waypoint following.
        iii. Navigation system - The entire navigation system will be tested for integration effectiveness. The subsystems involved: vision, sensor fusion, position control, localization, etc.
        iv. Autonomous position locking - The system must be able to lock around a position in order to hover over the dock in preparation for landing. This integration test covers the same subsystems of the navigation system.
    c. Location: NSH B-Level Basement
    d. Equipment:
        i. Iris+ Drone
        ii. Wellhead infrastructure with identifying tag
    e. Personnel:
        i. Cole Gulino - will be the operator who is required to run the commands for the drone.
        ii. Erik Sjoberg - will be the backup operator for manual control of the Iris+ in case of emergency.
    f. Procedure:
        i. Cordone off the area in the B-Level basement for safety.
        ii. Under manual control, take off with the drone and move into desired initial position and orientation.
        iii. Run the command to commence the cone-search.
        iv. Observe as the Iris+ autonomously navigates the predefined cone-search trajectory until it has located the wellhead and locked on the position of the dock next to it.
        v. Verify that the Iris+ has position lock with the dock within the tolerance specified in the Verification Criteria.
    g. Verification Criteria:
        i. Iris+ has completed its cone-search maneuver.
        ii. Iris+ is hovering over around the center of the tag on the wellhead with a tolerance of 0.5m in any direction.

8. Integrate the subsystems
    a. Objective: By showcasing the integration of the subsystems involved with these three functional elements, we will showcase that the integration for all three functional areas has been completed in the simplest case.
    b. Elements: This test will feature the following elements:
        i. Vision subsystem - In order to recognize and lock on dock position, we must showcase that the vision system is able to recognize tages and get position estimates from them.
        ii. Control subsystem - In order to send waypoint information for the predefined cone-search path, we must have accurate position control in order to have waypoint following.
        iii. Navigation system - The entire navigation system will be tested for integration effectiveness. The subsystems involved: vision, sensor fusion, position control, localization, etc.
        iv. Autonomous position locking - The system must be able to lock around a position in order to hover over the dock in preparation for landing. This integration test covers the same subsystems of the navigation system.
    c. Location: NSH B-Level Basement
    d. Equipment:
        i. Iris+ Drone
        ii. Wellhead infrastructure with identifying tag
        iii. Dock infrastructure with identifying tag
    e. Personnel:
        i. Cole Gulino - will be the operator who is required to run the commands for the drone.
        ii. Erik Sjoberg - will be the backup operator for manual control of the Iris+ in case of emergency.
    f. Procedure:
        i. Cordone off the area in the B-Level basement for safety.
        ii. Under manual control, take off with the drone and move into desired initial position and orientation.
        iii. Run the command to commence the cone-search.
        iv. Observe as the Iris+ autonomously navigates the predefined cone-search trajectory until it has located the wellhead and locked on the position of the dock next to it.
        v. Verify that the Iris+ has position lock with the dock within the tolerance specified in the Verification Criteria.
        vi. Verify that the Iris+ has successfully landed on the docking infrastructure.
    g. Verification Criteria:
        i. Iris+ has completed its cone-search maneuver.
        ii. Iris+ is hovering over around the center of the tag on the wellhead with a tolerance of 0.5m in any direction.
        iii. Iris+ has docked with 5 DOF.

9. Preliminary full system integration
   a. Objective: The purpose of this test is to prepare a simplified version of our complete SVE. This will force us to complete the integration of our various sub-systems in preparation for the final demonstration. This demonstration will not have the polish of our final SVE, however it should contain each of the major required elements in more-or-less working order. Some minor intervention or restarts may be required, but will be allowed.
   b. Elements: This test will feature the following elements:
      i. Vision subsystem - In order to recognize and lock on dock position, we must showcase that the vision system is able to recognize tages and get position estimates from them.
      ii. Control subsystem - In order to send waypoint information for the predefined cone-search path, we must have accurate position control in order to have waypoint following.
      iii. Navigation system - The entire navigation system will be tested for integration effectiveness.
      iv. Autonomous position locking - The system must be able to lock around a position in order to hover over the dock in preparation for landing.
      v. Autonomous docking - The system will complete the full docking procedure.
   c. Location: NSH B-Level Basement
   d. Equipment:
      i. Iris+ Drone
      ii. Wellhead infrastructure with identifying tag
      iii. Dock infrastructure with identifying tag
      iv. Warning tape
   e. Personnel:
      i. Erik Sjoberg - Erik will be the operator who is required to run the commands for the drone.
   f. Procedure:
      i. Cordon off section of hallway
      ii. Place wellhead at one corner of search area and dock 1m in front of the wellhead
      iii. Place Iris+ on ground at opposite corner of search area facing wellhead within +/- 5 degrees
      iv. Hit START button on PC to initiate sequence
      v. Confirm Iris+ lifts off and begins searching for wellhead (marker)
      vi. Confirm Iris+ arrives within 3 meter radius of wellhead
      vii. Confirm Iris+ orients above dock in pre-docking position (within 1 meter of dock)
      viii. Confirm Iris+ successfully lands in dock, constrained in 5 DOF
      ix. Restart from procedure iii. if unsuccessful
   g. Verification Criteria:
      i. Iris+ autonomously takes off from ground
      ii. Iris+ arrives within 3 meter radius of wellhead
      iii. Dock with docking station, constrained in 5 DOF
      iv. Multiple attempts along with some manual intervention will be allowed

10. SVE Preview Demonstration
    a. Objective: The purpose of this test is to prepare a more-or-less complete version of our SVE. This will be the first demonstration which requires a fully working system without manual intervention. Multiple restarts may be required, but the system must work autonomously.
    b. Elements: This test will feature the following elements:
        i. Vision subsystem - In order to recognize and lock on dock position, we must showcase that the vision system is able to recognize tages and get position estimates from them.
        ii. Control subsystem - In order to send waypoint information for the predefined cone-search path, we must have accurate position control in order to have waypoint following.
        iii. Navigation system - The entire navigation system will be tested for integration effectiveness.
        iv. Autonomous position locking - The system must be able to lock around a position in order to hover over the dock in preparation for landing.
        v. Autonomous docking - The system will complete the full docking procedure.
    c. Location: NSH B-Level Basement
    d. Equipment:
        i. Iris+ Drone
        ii. Wellhead infrastructure with identifying tag
        iii. Dock infrastructure with identifying tag
        iv. Warning tape
    e. Personnel:
        i. Cole Gulino - who will be the operator who is required to run the commands for the drone.
        ii. Erik Sjoberg - will be a standby operator to manually control drone in an emergency situation
    f. Procedure:
        i. Cordon off section of hallway
        ii. Place wellhead at one corner of search area and dock 1m in front of the wellhead
        iii. Place Iris+ on ground at opposite corner of search area facing wellhead within +/- 5 degrees
        iv. Hit START button on PC to initiate sequence
        v. Confirm Iris+ lifts off and begins searching for wellhead (marker)
        vi. Confirm Iris+ arrives within 3 meter radius of wellhead
        vii. Confirm Iris+ orients above dock in pre-docking position (within 1 meter of dock)
        viii. Confirm Iris+ successfully lands in dock, constrained in 5 DOF
        ix. Restart from procedure iii. if unsuccessful
    g. Verification Criteria:
        i. Iris+ autonomously takes off from ground
        ii. Iris+ arrives within 3 meter radius of wellhead
        iii. Dock with docking station, constrained in 5 DOF

Spring Validation Experiment

Needed Equipment: Iris+ with hardware, wellhead, dock, caution tape, blast shields
Operational Area: 25m^2 in B - Level Basement
Test Process:

1. Cordon off section of hallway and place blast shields to protect spectators
2. Place wellhead at one corner of search area and dock 1m in front of the wellhead
3. Place Iris+ on ground at opposite corner of search area facing wellhead within +/- 5 degrees
4. Hit START button on PC to initiate sequence
5. Confirm Iris+ lifts off and begins searching for wellhead (marker)
6. Confirm Iris+ arrives within 3 meter radius of wellhead
7. Confirm Iris+ orients above dock in pre-docking position (within 1 meter of dock)
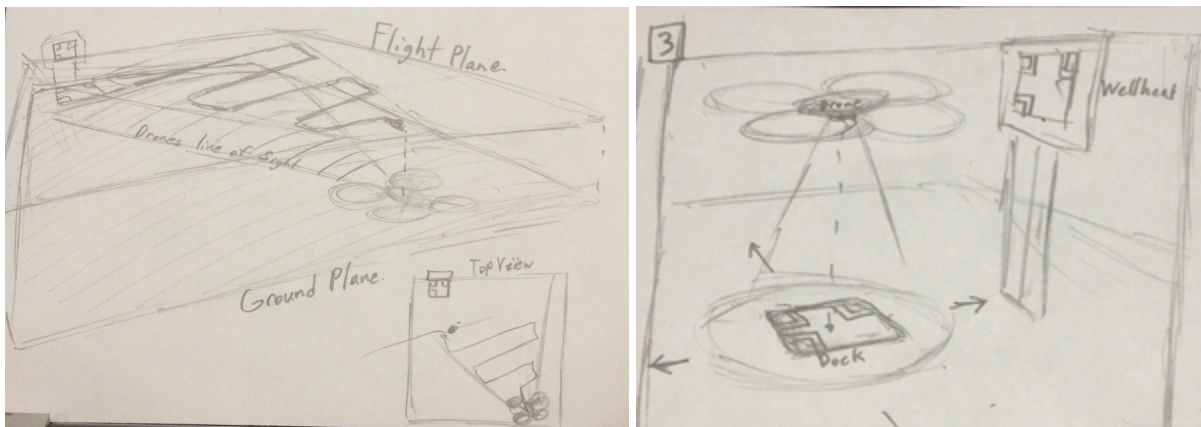8. Confirm Iris+ successfully lands in dock, constrained in 5 DOF

Success Conditions:
Mandatory:
1. Iris+ autonomously takes off from ground
2. Iris+ arrives within 3 meter radius of wellhead
3. Dock with docking station, constrained in 5 DOF

Desired:
1. Dock constraints 6 DOF
2. Successfully avoid obstacles

Schematic illustration of SVE Process:
Left: Drone searches for wellhead. Right: Drone locks onto dock, and proceeds to land.